SUMMARY OF PUBLISHED INFORMATION ON LARGE-CAPACITY COMPRESSED-AIR RECEIVERS FOR UNDERGROUND MINES

BY ANDREW ALLAN, JR.

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SUMMARY OF PUBLISHED INFORMATION ON LARGE-CAPACITY, COMPRESSED-AIR RECEIVERS FOR UNDERGROUND MINES

by

Andrew Allan, Jr. 1/

INTRODUCTION

Although the advantages of large-capacity air receivers for underground mines are plainly evident from published information about various installations in the United States and abroad, details of their construction are not generally known in this country. Ordinary present-day air-compressor installations servicing mining machines are designed to supply air at a specified pressure in sufficient quantity to meet the peak demand of the mine,2/ although this demand may exist for only a few minutes out of 24 hours and, as usually happens, eventually exceeds the capacity of the compressor. Most of the receivers provided with these compressors (to a certain degree of standardization) are capable of storing a volume of air approximately equal to that compressed in 1 minute by the machine.3, 4/ As a result, during peak-load periods the compressor operates at full load capacity without maintaining kick-off pressure. At other periods of the work cycle, production of compressed air is intermittent.

At least one large mine5/ has adopted large-capacity receivers to reduce wear on its air-compressing system caused by the sudden demand of peak loads. Under the old system, the compressors jumped suddenly from half speed to full speed; boilers furnishing steam to the compressors were taxed heavily to provide the increased requirements of power; and machines using the air, among which were four large hoists, were required to operate at 65 pounds per square inch rather than at the 90 pounds per square inch for which the compressors were regulated. Operation of air machines, especially drills, at pressures lower than those for which they were designed decreases their efficiency and increases maintenance costs. In addition, air that comes directly from the compressors has had little opportunity to cool and dry enroute.6/ As a result, quantities of compressor lubricant and water are carried into the machines that use the air. When expansion occurs in the cylinder or turbine of such engines, the temperature of the air drops, and this oil and water is precipitated. The water washes away lubricating oils in the machine, causing poor performance and high cost of maintenance; the compressor oil, in addition to being a poor lubricant for compressed-air engines, exerts a corrosive action on gaskets and rubber hoses.7/

1/ Mining engineer, Anthracite Mechanical Mining Section, Bureau of Mines, Schuylkill Haven, Pa.
2/ Compressed Air Data, 5th ed., 1939, p. 167.
3/ See part 1.
4/ See footnote 2, pp. 215-216.
5/ See part 2.
6/ See footnote 2, pp. 155-156.
7/ See footnote 2, p. 156.

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Reduction of peak demands on air compressors by large receivers lowers power costs by establishing more nearly constant load factors,[8] and in some cases by permitting the use of smaller compressor capacity.[8,9]

Load factor is the ratio of average demand to maximum demand; a low load factor costs money.[10] Elimination of high-peak demands raises the load factor by making the average and the maximum demand more nearly equal. Further savings may be made possible by large receivers where their use permits charging to be done at night in regions having lower power rates during that period.[11]

Where ordinary receivers are used, compressor breakdowns cause immediate work stoppages in the mine owing to lack of air. Similarly, the capacity of a large receiver has been known to permit uninterrupted work in the mine until the compressors have been returned to service.[9]

Large-capacity receivers, either steel-tank or underground rock-chamber, offer a practical solution of many existing problems by providing a sufficient reserve of compressed air within the pressure range required for efficient operation of machines to level off peak demands on the compressor. The compressors operate when the demand has reduced the pressure in the receiver below the regulating pressure and until all air used from the receiver has been replaced. It has been found possible in at least two mines,[8,9] one of which the author has visited, to entirely eliminate one compressor and to obtain more efficient performance from the remaining one by the construction of an underground coal-chamber receiver.[8]

Although receivers such as this provide enough air to operate machines for comparatively long periods, this is accomplished at continuously diminishing pressure.[8,9] In some instances, when a suitable column of water can be established and connected to such a receiver, hydrostatic head is used to maintain constant pressure for the entire volume of air so stored.[3,5,11]

Most mines have chambers of some kind which have been mined and left standing open. Relatively little work is required to convert such chambers into compressed-air receivers by the installation of suitable bulkheads (mine dams) and perhaps some grouting. Formulae for the calculation of bulkheads may be obtained from standard mining handbooks.[12,13] Savings in power and maintenance are possible even in such small installations as the Roslyn mine,[9] where compressor capacity was only 405 cubic feet per minute before the receiver was built.

8/ See part 5.
9/ See part 4.
10/ Sec. III, Power: Mechanical, 1941, p. 109.
11/ See part 6.
12/ Drainage of Mines: Peele's Mining Engineers' Handbook, 2d ed., 1927, sec. 3, art. 3, p. 1167.
13/ Mine Drainage and Pumping Machinery: Coal Miners' Pocketbook, 12th ed., pp. 888-889.

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Interest shown in large-capacity receivers by mining companies of the anthracite region of Pennsylvania has prompted the Bureau of Mines to list and review all published information on underground-receiver installations as a guide for those who may wish to construct such a receiver.

Following is a list of published articles pertaining to such air receivers, with a brief summary of the contents of each.

Part 1. New Development in Compressed-Air Storage

By Frank Richards: Machinist, Aug. 31, 1911, pp. 409-410

This is a short article on the adaptation of large-capacity receivers to the conversion of 25 large hoists (total capacity 40,000 hp.) of the Anaconda Copper Mining Co. at Butte, Mont., from steam to compressed-air motive power. Three compressors of about 20,000 cubic-feet-per-minute combined capacity store air in 32 steel-tank receivers having a total volume of 70,000 cubic feet (500,000 cu. ft. free air at 90 lb.-per-sq.-in. gage pressure). Hydrostatic pressure on these receivers makes their entire content of compressed air available for use at full pressure. Because no valves are used on the water lines and the surface of the water tank is exposed to atmospheric pressure, air pressure in the receivers cannot exceed that created by the column of water.

Part 2. Compressed Air-Equalizing System at Copper Queen

By Fred M. Heidelberg: Engineering and Mining Journal, Dec. 25, 1925, pp. 1047-1049

Describes the centralization of the compressed-air power supply at Copper Queen Consolidated Mining Co. in Bisbee, Ariz., during the years 1908 to 1915. Air machines consisted of four large shaft hoists, several hundred air drills, and many other kinds of minor hoists and air machines. Average air consumption for 1912 was 10,000 cubic feet per minute; maximum was 14,000 and minimum 2,000. Air was supplied by two 3,500 cubic-feet-per-minute I-R compressors and one 7,000 cubic-feet-per-minute Nordberg compressor connected directly to the line. Wide variation between maximum and minimum resulted in undue strain and wear on the compressors and steam-generating plant in addition to great fluctuations in air pressure at the hoists and other machines when full, steady pressure was needed. To correct this situation, an air-storage and balancing system was devised and built.

The article contains a good description, with two figures, of the installation of a large-capacity, steel-tank storage system for air, in which constant pressure is maintained by hydrostatic head. The combined capacity of 6 tanks is 15,000 cubic feet, or 115,000 cubic feet of free air at 93 pound-per-square-inch gage. Difference in elevation between the bottom of these tanks and the bottom of the water-storage tank is 208 feet. A 1-foot drop of the water level in the tank displaces 21,000 cubic feet of free air at 93 pounds per square inch in the air tanks. Charts of air pressure before and after the installation of the receiver illustrate the marked improvement in pressure maintenance for the system.

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Part 3. Wirtschaftlichkeit und Ausgestaltung von prebluftspeichern Untertage (Economy and Construction of Compressed-Air Storage Chambers Underground)

Glückauf, vol. 61, Nos. 1 and 2, Jan. 3 and 10, 1925, pp. 1-8 and 40-44

This article, written in German, discusses conditions and possibilities of compressed-air storage, beginning with general basic principles. Savings and advantages of large-capacity underground receivers are contrasted with the cost of construction and leakage losses. The latter can be reduced to a minimum by proper construction, whereas the former depends on the size of chamber and quality of strata.

Briefly, the paper covers the following points, in order:

1. The basic reason for compressed-air storage.
2. Avoiding pressure fluctuations through larger pipe diameters and receivers.
3. Effect of compressed-air chambers on pressure variations (3 diagrams).
4. Actual examples of air storage and its influence on drill efficiency.
5. Size of air chamber.
6. Degree of efficiency.
7. Possible economies.
8. Leakage tests.
9. Pressure of overlying strata and damage from mining progress.
10. Kind of stratum.
11. Construction and leakage-prevention of bulkheads.
12. Costs.

Part 4. An Underground Rock Air Receiver

By Charles Pengilly: Institution of Mining and Metallurgy, Bulls. 437 and 438, Feb. 1941, 10 pp.
Discussion, Mar. 1941, pp. 1-3

This paper covers the construction, cost, and results of a large-capacity underground air receiver at the Tebekwe mine, Selukwe, Southern Rhodesia. Continued expansion of underground operations, which finally rendered existing air-compressor capacity inadequate, induced the company to attempt construction of this type of receiver. An old crosscut, which was driven in solid rock having every appearance of being suitable for the purpose, was used for the receiver. It is 1,150 feet long and has an approximate volume of 46,000 cubic feet. The text is illustrated by four sketches showing details of the concrete seal, or dam, in the crosscut.

First attempts to charge the receiver were made 6 weeks after the forms were removed from the concrete. Three compressors, having a combined capacity of 890 cubic feet of air per minute at 80 pound-per-square-inch pressure, charged the chamber to 30 pound-per-square-inch gage pressure in 1 hour and 45 minutes. At this point, pressure was released because of several leaks,

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which reduced the pressure 10 pounds per square inch in about 20 hours. A homemade, air-operated, concrete ram capable of producing a pressure of 250 pounds per square inch was then used to grout a total of 18 holes around the sides and back of the dam. Procedure for this work is fully described.

The second charging of the receiver took 5-1/2 hours and raised the pressure to 77 pounds per square inch. The few small leaks evident were not considered serious, as they reduced the pressure only 3 pounds per square inch in 17 hours and 40 minutes. However, grouting was again attempted at a pressure of 470 pounds per square inch without releasing the air in the receiver. Pressure drop is now 2 pounds per square inch per 24 hours, or about 10 cubic feet of free air per minute.

In discussing the advantages of the receiver, it is pointed out that even though one 299 cubic-feet-per-minute capacity compressor has been eliminated, air pressure can easily be maintained constant with those remaining. In addition, these compressors operate at more uniform load factors.

Included in the report is a table of cost data for the receiver and a comparison of this cost with that for installing larger air mains, as was suggested.

Five pressure charts illustrate conditions before and after construction of the receiver.

Discussion

Of particular interest is the discussion by A. Broughton Edge, who presents two ideas for sealing leaks that grouting would not seal in Pengilly's work. The first of these consists in spraying the sides of the chamber inside the dam with sodium silicate while full air pressure is maintained. As it covers the walls of the chamber, the solution will be forced by air pressure into the minute fissures that grouting would not reach.

An alternate method requires a second dam 30 feet or so inside the first one to be raised to within a few inches of the roof. The space between the two is then filled with water containing collodial aluminum silicate. Pressure in the chamber would force this into the fissures of the sides and floor, but the roof would still require spraying with the sodium silicate solution.

Part 5. Underground Air Receiver in a Coal Seam

By T. Murphy: Compressed Air Magazine, vol. 47, No. 12, Dec. 1942, pp. 6915-6917

Murphy relates how Pengilly's article (An Underground Rock Air Receiver) on the use of a blind drift at the Tebekwe mine, Southern Rhodesia, for an underground compressed-air receiver led to his adoption of the idea at mine No. 3 of the Northwestern Improvement Co., Roslyn, Wash. He furnishes a complete and detailed account of the construction of his 25,000 cubic-foot receiver and how it has enabled him to move one of his air compressors to

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another mine where it was needed. The remaining compressor now operates at better load factor. At peak demand, pressure in the receiver is lowered as much as 10 pounds per square inch, but the compressor is able to restore the original pressure by the time work is finished for the day.

An interesting problem in the elimination of methane gas, which is generated by the coal seam in which this chamber was driven, is included in this article. Should this gas be compressed and used by drills and other machines for power, it would create a hazard to the health and safety of the miners. The adopted solution and a method for periodic checking on the methane content of air in the receiver is described.

After grouting had been done around the bulkhead at 300 pound-per-square-inch pressure, leakage of the chamber was determined by filling it with water at 160 pound-per-square-inch pressure. A little loss was noted around the ends of the bulkhead through a 3-inch band of clay in the coal seam. This was grouted, and another hydrostatic test was made while the chamber was partly filled with air at 75 pounds per square inch, which revealed a loss of about 1 gallon per minute. The chamber was then filled with water, and a meter was attached to the drainage line. Measurement of the flow as this water was drained off showed the true volume of the receiver.

A method for calculating the quantity of air contained in one of these receivers and the length of time that volume will supply air at pressures suitable for drilling as outlined by Murphy should prove useful in determining the size of receiver required for a particular installation. In other words, the size of the receiver can be made such as to supply the maximum demand of the mine for 1 hour, 2 hours, or as long as is desired.

Part 6. Hydraulic Air-Storage Chambers in Swedish Mines

By Sven Dalhammer: Compressed Air Magazine, vol. 53, Feb. 1948, pp. 30-33

In a brief history of hydraulic compressed-air receivers, Dalhammer states that the first one was built in 1914 at the Dannemorra mines in Sweden. At about the same time, several of the nonhydraulic type were installed at other mines in that country, some in connection with hydraulic compressors. Advantages of the hydraulic system, however, were not recognized until 1927, when one was built at the Hillang mine. This type is now accepted as standard. Of those recently installed, the largest has a capacity of 140,000 cubic feet.

The Hillang receiver has a volume of 8,800 cubic feet, which is equivalent to 100,000 cubic feet of free air at 155 pound-per-square-inch pressure. The system, which is well-described, including an excellent sketch, consists essentially of a water reservoir on the 72-foot level connected by a 6-inch pipe line to an air chamber on the 463-foot level. The difference in elevation produces hydrostatic pressure on the contents of the air chamber. In this case the actual operating pressure is about 165 pounds per square inch. Data are also given on a method for determining the quantity and level of water in the water-storage chamber to produce the required pressure in the

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receiver. Advantages that have been obtained by the installation of these systems in Swedish mines are summarized at the conclusion of the article.

Part 7. Underground Rock Air Receiver

The Iron and Coal Trades Review, Feb. 21, 1941, p. 247

This article has not been summarized because it is the same as part 4.

Part 8. Rock-Hewn Air Receiver Deep Underground

Compressed Air Magazine, vol. 46, No. 7, Jul. 1941, p. 6494

This article has not been summarized because it is the same as part 4.

Part 9. Underground Rock Air Receiver

By Charles Pengilly: The Colliery Guardian, vol. 162, No. 4183, Feb. 28, 1941, pp. 197-198

This article has not been summarized because it is the same as part 4.

PATENTS

Search of the U. S. Patent Office in Washington, D. C., failed to disclose any patents relating to underground compressed-air receivers.

Part 10. An Underground Air Receiver

By R. W. Neyman: Mining Congress Journal, March 1948, pp. 50-51

When the Star mine, of the Sullivan Mining Co., was connected with Hecla main shaft of the Hecla Mining Co. by a 10,000-foot crosscut, the pressure drop in the 6-inch air line became prohibitive. Installation of a 2,000-cubic-foot-per-minute capacity compressor helped but did not solve the problem. Accordingly, a 9- x 10-foot crosscut 750 feet long was sealed by a concrete and steel bulkhead. Pressure is now maintained at 100 p.s.i. at all faces throughout the day.

Details of bulkhead construction are given in this article and are of particular interest because of the installation of a 4- x 6-foot steel door. The method described for sealing the rock adjacent to the bulkhead by grouting with cement and bentonite is also of value in the construction of this type of receiver.

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